[10191/2062]

METHOD AND DEVICE FOR ESTIMATING MEMORY-ENABLED TRANSMISSION CHANNELS

Field Of The Invention

The present invention relates to a method and a device for estimating memory-enabled transmission channels as used, e.g. in discrete-time communications systems, such as CDMA systems (CDMA = code division multiple access).

Background Information

When transmitting data via memory-enabled channels, data parts separated over time are superposed. The resulting intersymbol interference of the data can be eliminated if the pulse response of the transmission channel is known. So-called channel estimators are used to determine the pulse response. They use information regarding the transmitted signal or the form of this signal to derive channel coefficients from the received signal. The most widely used channel estimators are based on a matched filter for a completely known reference signal **r** having optimum autocorrelation properties, i.e., $\mathbf{r}^*\mathbf{r} \propto \delta$, as seen, for example, in K.D. Kammeyer's "Nachrichtenübertragung," 2nd Ed., Information Technology Series, Teubner, Stuttgart, 1996. Non-optimum autocorrelation properties can be linearly corrected, yet additive noise of the transmission channel to be estimated, as is inherent, e.g., in CDMA systems (CDMA = code division multiple access), generally results in coefficient estimations that are higher than the actual values. It is known to partially correct these inaccurate coefficient estimations using non-linear reworking. Thus, such a method, called the POCS method or POCS algorithm (POCS = projection onto convex sets), is known, for example, from the publication by Z. Kostic, M.I. Sezan and E.L. Titlebaum: "Estimation of the Parameters of a Multipath Channel Using Set-Theoretic Deconvolution", IEEE Trans. Comm., Vol. 40 (1992), 1006 - 1011. In this connection, reference is also made to the known MMSE algorithm (MMSE = minimum mean square error), which is described, e.g., in the K.D. Kammeyer monograph "Nachrichtenübertragung" cited above.

However, in the case of currently known corrections of additive interferences when estimating memory-enabled transmission channels, it is disadvantageous that the methods produce correction results having varying accuracy for interferences of varying intensity. Moreover, threshold operations discontinuously correct coefficient values in the vicinity of the threshold value, thereby resulting in unnecessarily bad corrections.

Summary Of The Invention

Therefore, the object of the present invention is to provide a method and a device for estimating memory-enabled transmission channels, which provides an improved estimation of the channels, the quality of the estimation being as least dependent as possible on the additive interferences of the transmission channel.

The present invention relates to a method for estimating memory-enabled transmission channels, having the following steps:

(a) Determining a first estimation $\hat{\underline{h}}$ of the transmission channel;
(b) Estimating the additive interferences of the transmission channel; and
(c) Correcting the first channel estimation of step (a) while taking into account the estimation of the additive interferences of step (b).

Preferably, in the method according to the present invention, first channel estimation $\hat{\underline{h}}$ of step (a) is carried out using a matched filter or a least squares estimation.

The device according to the present invention further includes a channel estimator and an estimator of the additive interferences acting on the received signal and further has a channel estimation correction that corrects the signal of the channel estimator while taking into the consideration the output signal of the estimator of the additive interferences.

Advantageously, the method provides improved estimations in comparison with other methods. The estimations are relatively independent of the intensity of the additive interferences. Small channel coefficients are estimated more precisely than in customary threshold value corrections. As a result, the new method can also be used to better equalize non-Nyquist pulse shaped signals.

Brief Description Of The Drawings

Figure 1 shows a block diagram of the device according to the present invention, for estimating memory-enabled transmission channels.

Figure 2 shows the layout of a channel estimator.

Detailed Description

Figure 1 shows a channel estimator 1 as well as a parallelly situated interference estimator 2, both of which receive a received signal 4, and shows a channel estimation correcting element 3, which corrects the signal from channel estimator 1 with the aid of the output signal of interference estimator 2 and outputs channel estimation 5.

To further clarify the operating mode of the device of the present invention, a discrete-time communications system is given that transmits a reference signal $\underline{\mathbf{r}} = (\mathbf{r}_1,\ldots,\mathbf{r}_L)$ for purposes of channel estimation. A data signal $\underline{\mathbf{s}} = (\mathbf{s}_1,\ldots,\mathbf{s}_L)$, whose cross correlation to reference signal $\underline{\mathbf{r}}$ tends to zero, can optionally be transmitted at the same time. This case is representative of CDMA systems, which simultaneously transmit reference information and data information using orthogonal CDMA codes. Power P_S of data signal $\underline{\mathbf{s}}$ is f-fold power P_r of reference signal $\underline{\mathbf{r}}$, i.e., $P_S = f \cdot P_r$. In this context, the state $f = 0$ corresponds to systems that transmit reference signals and data signals separately with respect to time. The transmitted signal is transmitted via a static multi-path channel with the pulse response $\underline{\mathbf{h}} = (\mathbf{h}_1,\ldots,\mathbf{h}_W)$, W being the number of chip pulses in CDMA, and with additive Gaussian noise $\underline{\mathbf{n}}$, so that the following received signal results:

Equation (1) $\underline{\mathbf{e}} = (\underline{\mathbf{r}} + \underline{\mathbf{s}}) * \underline{\mathbf{h}} + \underline{\mathbf{n}}$

Then, $N = L - W + 1$ is the length of received signal part $\underline{\mathbf{e}}_{ref} = (\mathbf{e}_{refstart},\ldots,\mathbf{e}_{refstart+N-1})$, which is not influenced by data transmitted before or after the reference signal. Furthermore, let $E = \|\underline{e}_{ref}\|^2$ be the entire received energy of the received signal that was influenced by the reference signal. The term L is a length of the chip pulse indicating the pulse frequency of an individual pulse in CDMA. Depending on the device, channel coefficients $\mathbf{h}_k$, k 0 {1,...,W}, of pulse response $\underline{\mathbf{h}}$ are initially estimated by matched filter $\underline{\mathbf{r}}^*$-k corresponding to received signal $\underline{\mathbf{r}}$ to be $\underline{\hat{h}}$:

Equation (2) $$\underline{\hat{h}} = \frac{1}{\gamma} \cdot G^{*T} \cdot \underline{e}_{ref},$$

where

Equation (3) $$G = \begin{pmatrix} r_W & r_{W-1} & \cdots & r_1 \\ r_{W+1} & r_w & & r_2 \\ . & . & & . \\ r_{W+N-1} & r_{W+N-2} & \cdots & r_N \end{pmatrix}$$

and

Equation (4) $$\gamma = \frac{N}{L} \cdot \|\underline{r}\|^2 .$$

The layout of this estimator is represented in Figure 2, where γ is a scaling factor for the received energy and G is a matrix for describing the channel characteristics.

Using the following equation, intensity σ^2 of the additive interferences is subsequently estimated to be:

Equation (5) $$\sigma^2 = \theta\left(E - (1+\mathrm{f})\cdot\gamma\cdot\left\|\hat{\underline{h}}\right\|^2\right) / \left(N - (1+\mathrm{f})\right)$$

In this context, the following definition was met, where f is a frequency term:

Equation (6) $$\theta(x) = \begin{cases} x, & \text{if } x > 0 \\ \text{otherwise}, & 0 \end{cases}$$

Subsequently, the estimated channel coefficients $\hat{h}_k$, k 0 {1,...,W}, of estimated pulse response $\hat{h}_k$ is corrected using the following formula:

Equation (7) $$\hat{h}_k = \sqrt{\theta\left(\hat{h}_k^2 - \sigma^2/\gamma\right)} \cdot \hat{h}_k / \left|\hat{h}_k\right|, \quad \text{if } \hat{h}_k \neq 0, \text{ and}$$

otherwise

Equation (8) $$\hat{h}_k = 0$$

Figure 2 shows the calculating scheme of the above described channel estimator having a matched filter structure. Since the diagram in the above was already explained and Figure 2 is largely self-explanatory, it is not necessary to describe Figure 2.